BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 12034

SUBJECT: Communications Coverage for Modular Space Station Mission with Three MSFN Stations
Case 900

DATE: December 15, 1970

FROM: R. K. Chen

ABSTRACT

A brief study was made of the communications coverage provided for a modular space station mission using a minimum number of MSFN stations. The assumed criteria for coverage is that no communications gap be greater than 4.5 hrs. and a minimum of 3 minutes per contact. The combination of three MSFN stations, Hawaii, Goldstone, and Madrid, meets the maximum gap criterion, and provides (1) about 128 minutes per day of contact time for a space station in orbit at 242 nm altitude and at 55° inclination, and (2) 140 minutes per day of contact time for a space station at 270 nm altitude and 55° inclination of the orbital plane.

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MEMORANDUM FOR FILE

The concept of a modular space station is to assemble a space station in earth orbit with modules delivered to the orbit by space shuttles. These modules would be restricted in size to approximately 14 ft. in diameter and 58 ft. long; they would also be restricted in weight to about 20,000 to 25,000 lbs. each. The modular space station would serve as a manned multi-purpose, scientific and engineering laboratory in space for a 10 year life-time. The orbit planned for the modular space station is circular with an altitude somewhere between 240 and 270 nm, and the orbital plane would be inclined 55° with respect to the equator.

The communications coverage for such a long duration mission could be supported by two methods; one is the present Apollo method of using MSFN ground stations and the other could use a Data Relay Satellite System (DRSS) providing a direct relay between the spacecraft and one or two ground stations in the United States. This memorandum examines the use of a minimum number of MSFN stations for communications coverage with the criteria that the maximum communications gap between contacts should be less than three orbital periods of the space station, approximately 4.5 hrs., and the minimum coverage time per contact is three minutes.

In general, for a given inclined spacecraft orbit, ground stations that are located in latitudes near but several degrees less than the orbital inclination of the spacecraft would provide the best coverage, both in terms of the frequency of contacts and duration of contacts. This is seen in Figures 1 and 2, which illustrate the parametric relations of ground station latitudes and modular space station orbit at two altitudes, 242 and 270 nm. The best latitude for the ground stations for an orbital inclination of 55° should be somewhere between 40 and 45 degrees north or south. It can be shown that two ground station sets situated at these latitudes could provide coverage approximately once per revolution; each station would provide seven consecutive contacts alternately. The statement is approximately true for the altitude regime under discussion. It applies more exactly at 270 nm than at 240 nm altitude. The 270 nm, 55°

inclination orbit, however, has a unique characteristic: its ground track repeats almost exactlv after every 14 revolutions (about 23 hours and 40 minutes). Therefore, in order to assure coverage for seven consecutive revolutions, the ground station location in both latitude and longitude must be selected carefully. In actual practice, because of the terrain masking of the ground station and the perturbations of a circular orbit, the coverage behavior of the two-station set would more likely to have a mixture of six and seven consecutive revolution coverages. The end result is instead of having coverage once per revolution, there will be occasional coverage gaps of two revolutions (approximately 190 minutes). The two two-station sets are:

1. two stations located at approximately the same longitude, one north and one south, and

2. two stations located about 180° apart in longitide, but both at the same north or south latitude.

The stations considered are the twelve existing MSFN land-based stations which are shown in Table 1 with their coordinates. It is apparent from Table 1 that a two-station set outlined above is not available; moreover, only one station, Madrid, lies in the desired latitude of 40 to 45°. The two stations that come closest to the ideal two-station set are Madrid and Goldstone; their longitudinal separation is about 112° instead of close to 180° and Goldstone is closer to 35° latitude than 40° latitude north. It is obvious additional station(s) would be needed to provide once per revolution coverage; it is not clear, however, which station(s), if any, may be needed to satisfy the assumed 270 minutes maximum gap size criterion.

The analog technique of using ground track and station coverage map was used to determine the need and the location of the gap-filling station(s). Briefly, knowing the coverage contours of Madrid and Goldstone and the orbital period of the spacecraft (about 100 minutes per revolution), two sets of ground tracks can be sketched on the map; each set (two ground tracks) represents the ground tracks before entering and after leaving the coverage contours of the stations. The four ground tracks form the physical boundaries of the communications gap areas. This is illustrated in Fig. 3 where the shaded areas are marked Goldstone-to-Madrid gap and Madrid-to-Goldstone gap. The time associated with these gaps can be estimated by measuring the gap distance along the equator in degrees, and every degree is approximately 4 minutes in time, which is the rotational rate of the earth. From Fig. 3, the

Madrid-to-Goldstone gap is about 48 degrees or 192 minutes, and the Goldstone-to-Madrid gap is about 95 degrees or 380 minutes. Therefore, the Goldstone-to-Madrid gap exceeds the 270 minutes maximum gap criterion and needs plugging. Compare the gap area and the available MSFN stations, Hawaii appeared to be the needed third station.

The estimates made from the analog analysis was confirmed by the results of a computerized coverage program. Tables 2 and 3 shows the contacts and gap times provided by these three MSFN stations for space station orbits at 270 nm and 242 nm with 55° orbital inclination. The 270 nm orbit's coverage pattern repeats every 14 revolutions and the 242 nm orbit's coverage pattern repeats approximately every 85 revolutions. It is seen from Tables 2 and 3 that the maximum gap time is about 245 minutes; the average coverage time per day is about 128 minutes for the 242 nm orbit and 140 minutes for the 270 nm orbit.

Acknowledgement

The author would like to acknowledge the help provided by Messrs. J. P. Maloy and W. L. Austin in making the computer runs which supplied the data for this memorandum.

2034-RKC-ms R. K. Chen

Attachments
Tables 1, 2, 3.
Figures 1, 2, 3.

TABLE 1

MSFN STATIONS AND THEIR COORDINATES

STATION NAME AND SYMBOL	LONGITUDE (DEGREES EAST)	LATITUDE (DEGREES)
1. CAPE KENNEDY (MIL)	274.3066	28.5083N
2. SANTIAGO (SAN)	290.0000	33.0000S
3. BERMUDA (BDA)	295.3419	32.2503N
4. CANARY ISLANDS (CYI)	344.3653	27.7644N
5. ASCENSION (ACN)	345.6728	7.9547S
6. MADRID (MAD)	355.8306	40.4550N
7. CARNARVON (CRO)	113.7255	24.9066S
8. GUAM (GWM)	144.7369	13.3103N
9. HONEYSUCKLE (HSK)	148.9783	35.5837S
10. HAWAII (HAW)	200.3344	22.1264N
11. GOLDSTONE (GDS)	243.1267	35.3417N
12. TEXAS (TEX)	262.6217	27.6539N

REVOLUTION	1 REVOLUTION							1 REVOLUTION							1 REVOLUTION						1 REVOLUTION								
		MAD		HAW		GDS			MAD		HAW		GDS			MAD		HAW		GDS			MAD		HAW		GDS		
1-4		6.7		69.7		7.1	13.5		9.2		65.6		9.8	12.5		9.5	[illegible]	9.7	[illegible]	6.4		81.4			5.7				
5-8							201.9						8.8			[illegible]				9.4		[illegible]			4.8			90.2	
9-12				9.8										243.2									9.2			87.8			
13-16		9.4			90.0				6.9			92.1				6.3				5.3	[illegible]		8.9		66.8		9.9	12.4	
17-20		9.7	56.2	9.5	1.3	7.3	15.6		3.4	61.2	7.3																8.3	88.4	
21-24						9.8						180.8						9.7				[illegible]			4.2			149.7	
25-28									8.5			87.9				9.7							7.4			91.9			
29-32		6.1			91.2				8.5		66.2		9.8	12.4		9.9		8.8		8.0		[illegible]	5.9	[illegible]	8.3				
33-36							201.2						7.5			[illegible]				9.8			[illegible]				4.6	86.9	
37-40				9.4			88.8				6.7												7.7			88.0			
41-44		9.8			89.0				7.9			91.6				6.1			[illegible]				8.0		66.9		9.5	12.5	
45-48		9.8	57.1	7.8	1.0	8.7	13.6		7.4	67.8	9.1																6.7	89.5	
49-52						9.8				88.5			6.7		[illegible]			8.9			[illegible]				8.1			148.8	
53-56									6.5			88.4				9.9			[illegible]				8.3			91.3			
57-60		6.1			91.8				7.6		67.5		9.1	12.7		9.7	[illegible]	6.1	[illegible]	9.2	[illegible]		8.3	[illegible]	9.6	3.7	4.0	193.4	
61-64													5.7				[illegible]			9.6				[illegible]			7.9	85.6	
65-68				8.1			88.6				9.0						[illegible]						4.4			89.4			
69-72		9.8			88.2				8.7			90.9				6.3			[illegible]				7.1		68.4		8.4	13.0	
73-76		9.5		65.5		9.5	12.8		9.0	56.5	9.7	2.7	5.3							[illegible]							4.5	91.3	
77-80						9.3				88.0			8.8		[illegible]			6.8			[illegible]				9.6				
81-84								243.1								9.6			[illegible]				9.1			90.5			
85-88		6.5			92.1				6.7		69.6		7.2	13.5		9.2		[illegible]		9.8	12.8		9.5	[illegible]	9.7	1.9	6.4	81.5	

END OF 85 REVOLUTIONS, COVERAGE PATTERN REPEATS APPROXIMATELY EVERY 85 REVOLUTIONS

SUMMARY FOR 85 REVOLUTIONS:

MAX. GAP TIME = 243.1 MINUTES
TOTAL NO. OF CONTACTS = 96
TOTAL CONTACT TIME = 769.5 MINUTES

LEGEND:

9.2 CONTACT TIME IN MINUTES

52.3 GAP TIME IN MINUTES

TABLE 2 - COVERAGE FOR MODULAR SPACE STATION (3° GROUND STATION MASKING)
242 N. MI. ALTITUDE, 55° INCLINATION

REVOLUTION	1 REVOLUTION			1 REVOLUTION		
	MAD	HAW	GDS	MAD	HAW	GDS
1-2	7.7 69.5		8.0 13.0	10.0	65.7	10.5 12.1
3-4	10.2 56.2	10.5 1.2	7.2	81.8	6.3	106.4
5-6			5.1	92.1		9.8
7-8	88.5		9.9	85.9	7.0	89.8
9-10		10.4				
11-12		245.3		10.3	88.3	
13-14	10.0	90.6		7.6	92.3	

END OF 14 REVOLUTIONS, COVERAGE PATTERN REPEATS EVERY 14 REVOLUTIONS

SUMMARY FOR 14 REVOLUTIONS:

MAX. GAP TIME = 245.3 MINUTES
TOTAL NO. OF CONTACTS = 16
TOTAL CONTACT TIME = 140.5 MINUTES

LEGEND:

$\boxed{10.1}$ CONTACT TIME IN MINUTES
$\boxed{86.5}$ GAP TIME IN MINUTES

TABLE 3 - COVERAGE FOR MODULAR SPACE STATION (3° GROUND STATION MASKING)
270 N. MI. ALTITUDE, 55° INCLINATION

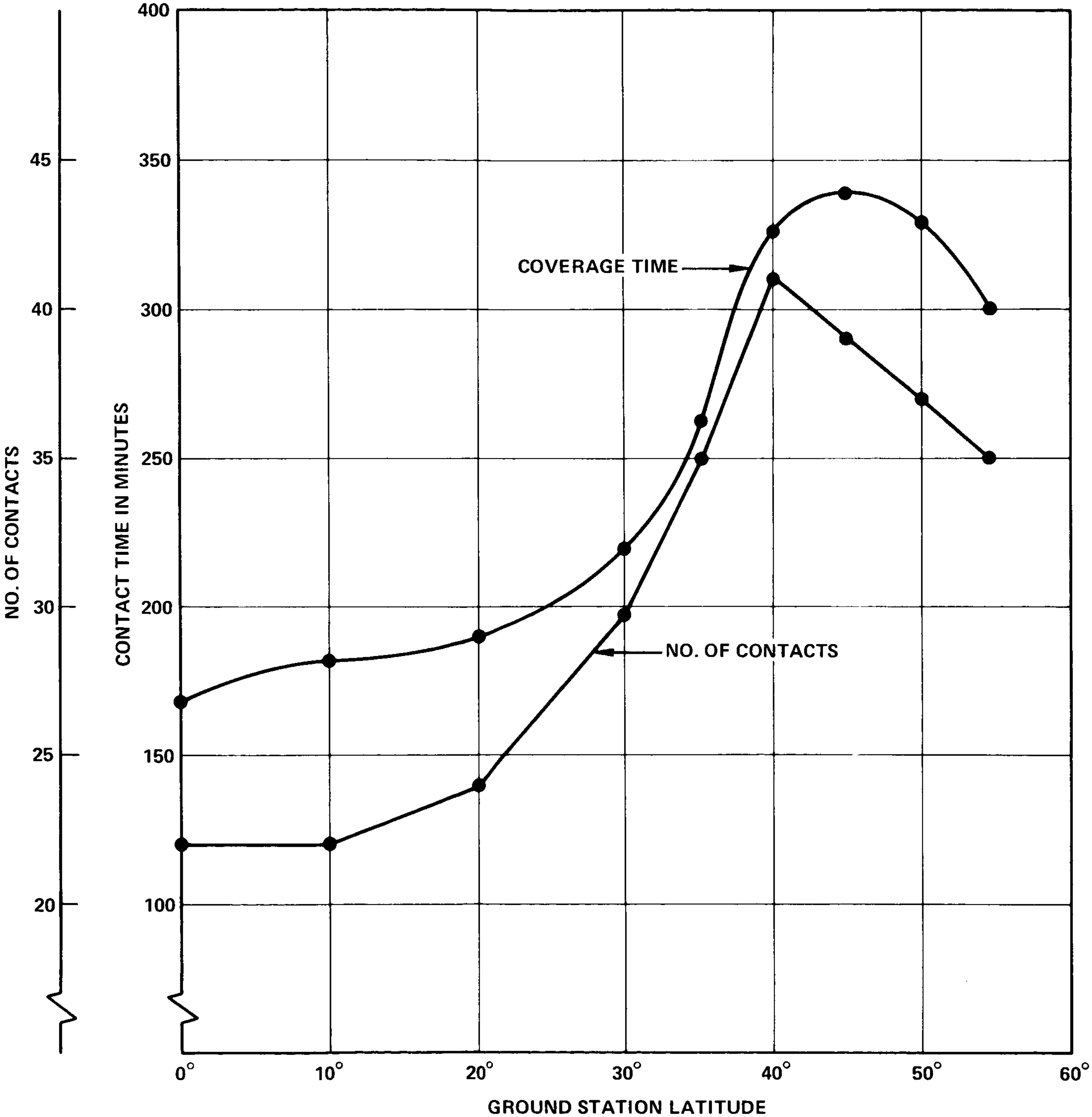

FIGURE 1 - COVERAGE CHARACTERISTICS FOR A SPACE STATION IN 242 N. MI. CIRCULAR ORBIT, 55° INCLINATION, IN APPROX. 6 DAYS

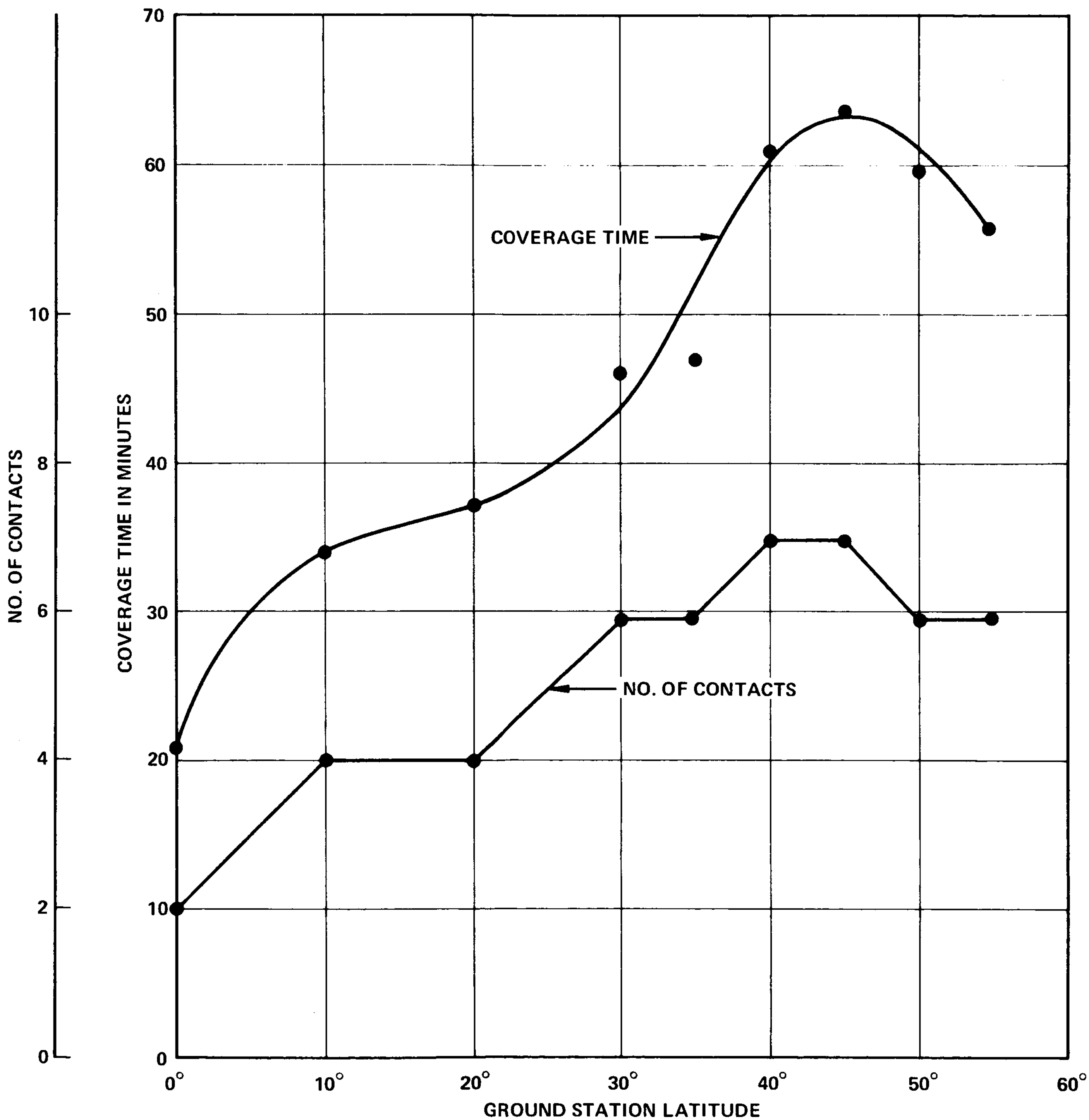

FIGURE 2 - COVERAGE CHARACTERISTICS FOR A SPACE STATION IN 270 N. MI. CIRCULAR ORBIT, 55° INCLINATION, IN APPROX. 1 DAY

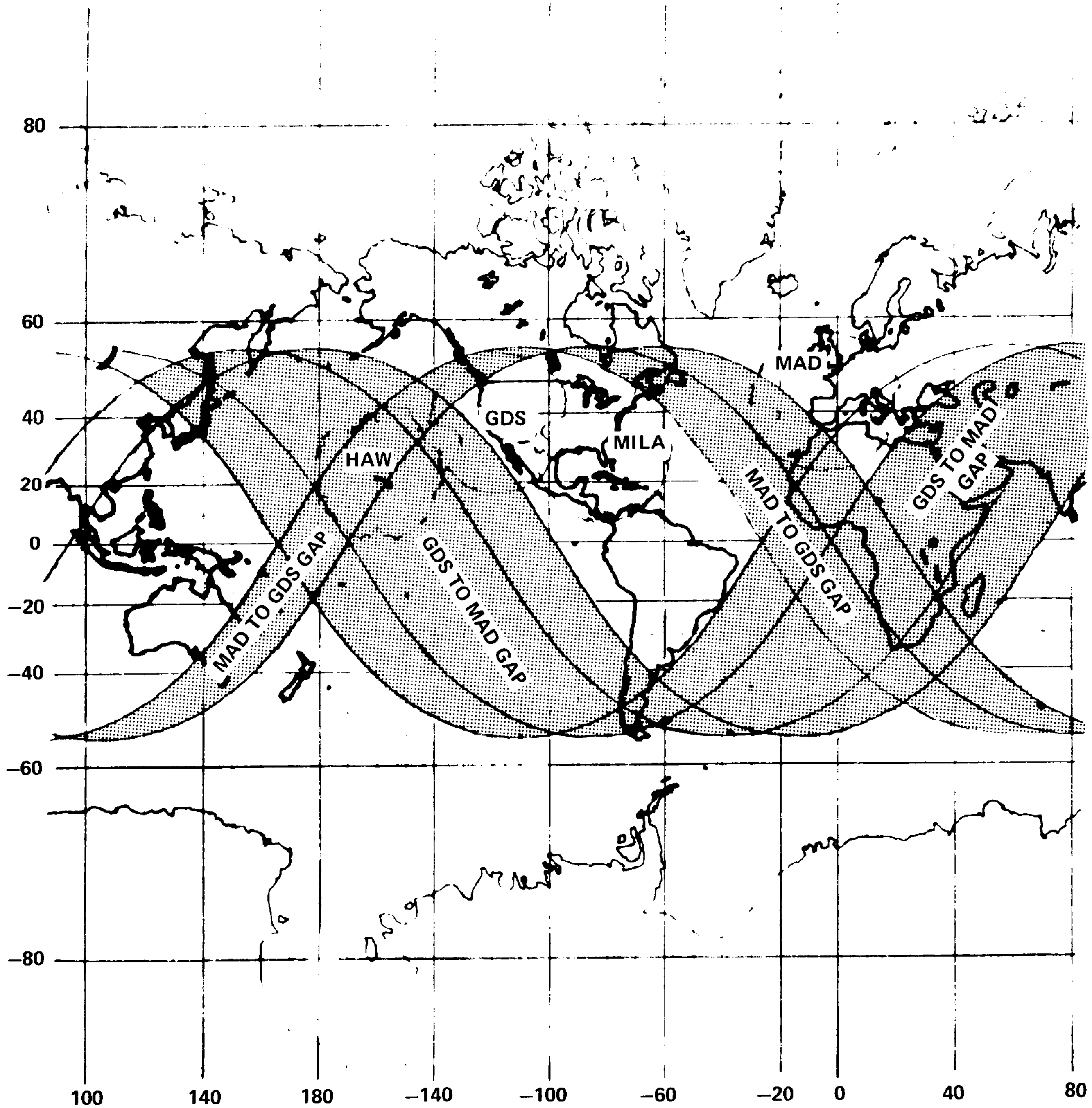

FIGURE 3 - COMMUNICATIONS COVERAGE GAP BETWEEN GOLDSTONE AND MADRID FOR SPACE STATION IN 270 N. MI. CIRCULAR ORBIT, 55° INCLINATION

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